TEDS, WEDS AND BEDS: A PROPERTY OWNER'S RETROFIT OPTIONS (A Step-by-Step Process)

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ANALYSIS OF RETROFIT OPTIONS

1) Model Existing Conditions:
   - Structure
   - Façade
   - Asset Locations for Valuable Equipment
   - People Locations at Varying Times of Day

2) Analyze range of Explosive Scenarios Chosen by the Property Owner
   - Car Bomb
   - Truck Bomb
   - Semi-Truck Bomb
   - Shrapnel Content of Bomb
   - Stand-Off Distance for Exterior Detonations
   - Stand-Off Distance for Interior Detonations

3) Analyze Existing Conditions Using Computer Simulation Analyses (See color isometric example)

4) Analyze Range of Retrofit Options Utilizing One or More Capital Improvements Chosen [Select any combination from (a) through (g)]:
   a) Clear the building perimeter with decorative barricades that can stop a truck in 3-feet, creating a larger stand-off distance for car and truck access than simple planter boxes or bollards (See TEDS);
   b) Increase the structure's elastic strength, so it can reflect blast overpressures without damage;
   c) Increase the structure's inelastic ductility, so it can dissipate blast energy with extreme structural damage;
   d) Increase life-safety by plastic wrapping columns and film coating windows to contain shattered concrete and glass shrapnel, with extreme structural damage;
   e) Increase structure's viscous damping, so it can better dissipate blast energy;
   f) Use the kinetic energy of sliding walls to first reflect a blast's overpressure and then sliding friction to dissipate the blast's impulse of energy, without damage (See WEDS);

g) Use the kinetic energy of an entire building to first reflect a blast's overpressure and then sliding friction to dissipate the blast's impulse of energy, limiting construction to basements or street level lobbies so upper stories are undisturbed (See BEDS).

5) Perform Computer Simulation Analyses for a Range of Explosive Scenarios and a Range of Potential Capital Improvements Chosen by the Property Owner.

6) Prepare Benefit / Cost Analyses and Report for the Property Owner's selection of an optimum solution.

RETROFIT SOLUTION

1) Analyses of all Retrofit Options selected by Property Owner.
2) Blast-test the chosen retrofit solution at White Sands, New Mexico or Vicksburg, Mississippi
3) Issue hard money contracts for supply and install.
4) Limit disruption of occupants and protect cash flow.
5) Fast track and expedite both supply and install contractors.

OPTIONAL DESIGN SOLUTIONS

MCA's unique methodology of approach always addresses the seven Retrofit Options, listed above as 4a through 4g. Three of these Retrofit Options are state-of-the-art energy dissipating systems, provided to Property Owners under Options 4a, 4f, and 4g, as defined below:

4a) Terrorist Truck Barriers: Truck Energy Dissipating System (TEDS),
4f) Terrorist Explosion Barriers: Wall Energy Dissipating System (WEDS),
4g) Terrorist Explosion Barriers: Building Energy Dissipating System (BEDS).

These three Retrofit Options, chosen from the seven listed above, are explained separately on the following pages because of their enhanced engineering applications. Each energy dissipating application is uniquely effective and low cost, having technology that's been fully tested and repeatedly proven during the past 200-years.

Although the technology is long proven, MCA's traditional policy is to subject every design application to physical performance tests, at White Sands, New Mexico or Vicksburg, Mississippi [See RETROFIT SOLUTION: Step 2 above]. We thereby provide Property Owners with inexpensive assurance of performance; ultra-conservatively proof testing design configurations before deployment.

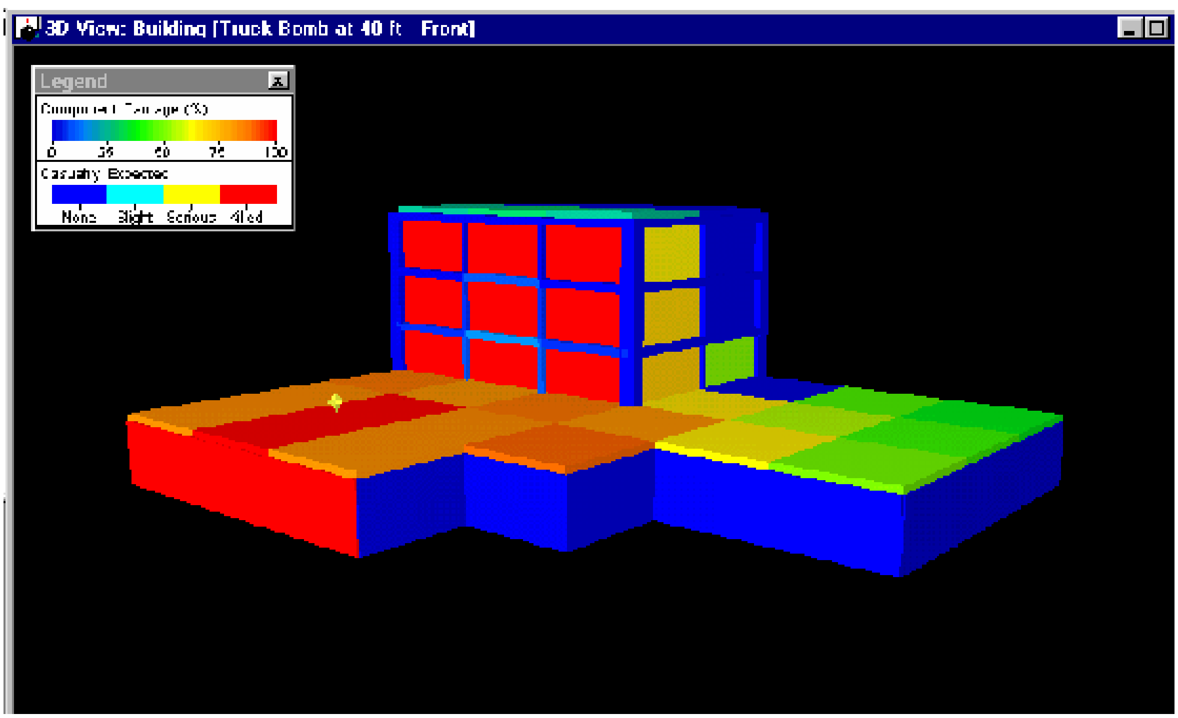
PROTECTING PROPERTY OWNERS
AGAINST TERRORIST ATTACK
WITH EFFECTIVE TRUCK BARRIERS AND EXPLOSION BARRIERS

ANALYSIS OF RETROFIT OPTIONS: METHODOLOGY OF APPROACH

Vulnerable buildings can be protected against blast damage. Retrofit Options to protect property against blast damage can result in higher standards of performance than attempting to protect against loss of life alone. Surprisingly, it's frequently less costly and less disruptive as well.

State of the art computer simulations of building exposure to blast damage can provide Property Owners with concise information about Retrofit Options. Computer simulation analyses will fully conform to both DoD and FAA requirements. Retrofitting to reduce exposure of existing structures to terrorist explosions need not be prohibitively expensive or disruptive of operations, and can frequently enhance earthquake resistance as well.

Blast scenarios for a range of TNT or C-4 explosives and charge locations are first analyzed for expected building damage as well as anticipated injuries. These analyses are graphically displayed, in color, and can be printed for evaluation and decision-making. Presented as 3-dimensional isometrics, they can be rotated to any desired viewing angle. Graphic displays use color codes to define structural damage, as well as injury to both people and equipment assets. Color-coding makes results concisely comparative and understandable for Property Owner's decision making (See following color graphic as example for a 3-story building in which the light blue girder and roof are on the verge of collapse, due to a "Ryder" Truck detonated 40 feet away).



RETROFIT SOLUTIONS

Blast analyses are first run for existing building conditions. A full range of chosen mitigation measures are then tested by simulation. Property Owners can evaluate the costs, benefits and disruption inherent to each Retrofit Option, evaluating combinations of mitigation measures. Retrofit Options may include:

- Protecting the building perimeter with decorative barricades that can stop a truck in 3-feet, creating a larger standoff distance for car and truck access than simple planter boxes or bollards.
- Increasing a structure's elastic strength, so it can be hardened to reflect a blast's overpressure without damage.
- Increasing a structure's inelastic ductility, so it can dissipate blast energy with extreme structural damage.
- Increasing life-safety by plastic wrapping columns and film coating windows to contain shattered concrete and glass shrapnel, with extreme structural damage.
- Increasing a structure's viscous damping, so it can better dissipate blast energy.
- Using the kinetic energy of sliding walls to first reflect a blast's overpressure and then sliding friction to dissipate the blast's impulse of energy, without damage.
- Using the kinetic energy of an entire building to first reflect a blast's overpressure and then sliding friction to dissipate the blast's impulse of energy, limiting construction to street level lobbies so upper stories are undisturbed.

Evaluating this full range of Retrofit Options permits Property Owners to make informed decisions concerning protection of property, lives, equipment assets and security.

EXTERIOR WALL STRENGTHENING TECHNOLOGY (WEST) (4F)

Many buildings built before 1960, when curtain wall construction first came into vogue, were not designed to conform to significant earthquake resistant criterion. Frequently lateral force seismic design capacity was limited to from two (2) to ten (10) percent of building weight. Many buildings built between 1900 and 1960 had vertical weight supporting systems of structural steel having simple rivet connections. Rivet connections have no capacity to resist any horizontal earthquake forces. Only the brittle but strong brick or concrete masonry exterior walls remained to prevent collapse in 1906.

Energy dissipation (Transforming seismic energy to heat by laterally bending the structural steel like a "paper clip" in modern buildings) is not necessary when enough elastic strength is provided. This was proven during the Richter Magnitude 8.3, 1906 San Francisco earthquake. To this day the 1906 San Francisco earthquake is the only strong-motion prototype test ever made on tall buildings in a major city.

Buildings with steel vertical weight supporting systems and strong masonry horizontal earthquake resisting systems up to 16 stories, withstood that 8.3 earthquake and <u>no buildings collapsed</u>. Even today the Mills Building, Flood Building, Monadnock

Building, Ferry Building, Sheraton Palace Hotel, St. Francis Hotel, Kohl Building, Call Building etc.; remain in service. Hence an elastic strength of twenty (20) percent a building's weight is a well-tested solution for retrofitting many similar buildings built between 1900 and 1960.

Exterior steel channel box frames can be used to rapidly and cost-effectively transform weak and brittle buildings into strong composite frames, using Wall Exterior Strengthening Technology (WEST). This solution enables raising the seismic lateral force resistance from two (2) percent to twenty (20) percent of building weight, without serious disruption of window visibility, ventilation, lighting or internal building functions during construction

The Wall Exterior Strengthening Technology (WEST) is shown on attached elevation and section drawings. Architectural appearance will be altered, but modern coloration can be applied in the shop to either blend steel channel box frames into the façade or blend it into the window coloration to emphasize the seismic solution visually.

Upgrading older structural steel and masonry buildings is feasible, and not overly costly or disruptive of internal building operations. Upgrading requires a combination of two factors:

1) **Stiffness,** to automatically attract lateral seismic forces away from weaker more flexible elements and towards stronger elements.

2) **Strength,** to resist horizontal seismic forces delivered by floors into wall elements, increasing strength from two (2) percent of building weight to twenty (20) percent.

The structural steel vertical weight supporting system of older buildings needs no strengthening. Retrofit is only required for the under-reinforced and very brittle concrete spandrel girders above the windows and the concrete piers adjacent to the windows, as these form older building's only seismic lateral force resistance system.

Prior to an earthquake, only the structural steel frame is experiencing stress and strain as it supports the building's weight. Lateral force resisting system components are totally unstressed and unstrained, until earthquake vibrations and their horizontal whiplash motions suddenly seek to find and fracture the building's weakest links.

To enhance its lateral force resisting system and protect older buildings against sudden fracture during an earthquake, piers and girders can be stiffened and strengthened with exterior steel box frames. These can be shop fabricated from rolled steel "channel" sections, twelve (12) inches to fifteen (15) inches deep, before cementing them to sound concrete all around the windowsills, jambs and headers with a non-shrink epoxy structural compound.

STIFFENING the frames in select bays is necessary to automatically attract lateral inertia forces away from weaker under-reinforced piers and spandrel girders, directing most of the lateral seismic forces into the newly strengthened bays. Existing rigid concrete floor diaphragms and deep wall spandrels will readily accomplish an automatic force transfer to the stiffened bays.

STRENGHTHENING the frames in select bays is accomplished by creating composite structural action between the new steel channel box frames and existing concrete as well as embedded structural steel. Embedded structural steel, new steel channel box frames and existing concrete elements will all be designed to work together during an earthquake.

Each newly strengthened bay can be thought to have composite structural steel and concrete frames at each story, rigidly cemented together as a unit and including both the existing weak piers and brittle spandrel girders. Shear transfer between new steel box frames and existing concrete contact surfaces, as well as internal mechanical locking mechanisms already existing between concrete and embedded structural steel, will serve to reduce seismic distortion and enhance lateral strength.

Composite action for the retrofit of typical steel frame and concrete spandrel buildings of this pre-1960's vintage, can best be visualized as a series of vertical towers. The vulnerable under-reinforced concrete piers and spandrel girders in these tower bays, will be transformed into heavily reinforced frames serving as buttresses against horizontal distortion. Shear stresses transferred between each story can be readily resisted in the composite mix of concrete and structural steel members, providing high safety factors against both collapse and loss of life during moderate earthquakes.

The existing structural steel columns on both sides of each reinforced tower bay will resist overturning moment in the stiffened bays. Story shear forces will be transferred into low-stress mechanical concrete bearings at girder to column joints, wedged by high compression friction forces that tri-axially confine and strengthen the concrete enclosed between structural steel flanges and webs. Shear transfer across the epoxy compound will be enhanced mechanically by scarifying the concrete during surface preparation and roughening the steel box channel contact surface in the shop with weld lines or weld spatter.

Repair provides rapid security for both people and valuable assets housed at older buildings. Repair includes seismic retrofit upgrade to a lateral force resistance standard of twenty (20) to thirty (30) percent the building's weight. This can be done by utilizing all available structural components, sandwiching existing concrete "webs" between composite steel "flanges." The WEST system is comprised of new steel window channel box frames, made composite on each side of each vertical concrete pier and horizontal concrete girder. Shear stresses and bearing stresses at composite connections are quite

low.


Installing channel steel box frames in every window permits each currently brittle pier and girder to be both strengthened and simultaneously transformed into “ductile” piers and girders. Ductility permits structural steel to flex during an earthquake, like a steel paper clip. With ductility as a backup at all composite piers and spandrel girders, no brittle elements remain to cause sudden collapse.

Cost for fabrication and installation is estimated conservatively at $20,000 per window frame, averaged over various window sizes.

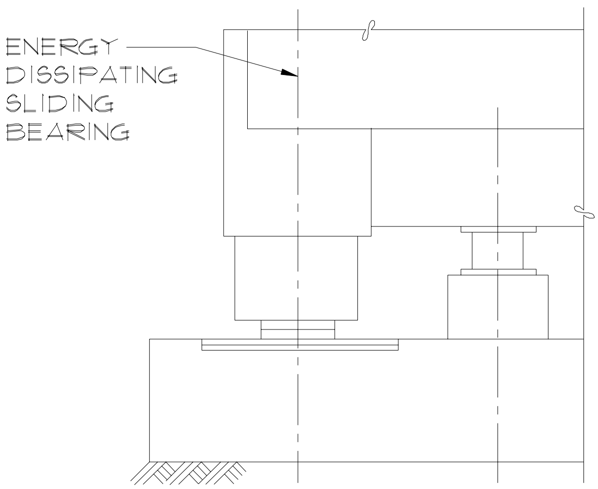
Comparison of Options for Seismic Retrofit Ratings

CRITERION / OPTIONS	Maximum Seismic Rating Attainable	Constr. Cost Estimate	Duration to Construction Completion From NTP	Column and Foundation Modification	Intrusion on Operations & Cash Flow	Noise and Vibration Causing Relocation	Window Operability for Light and Air	Visual Architecture Disturbance
1) Exterior Steel Cross-Bracing	"FAIR," If very strong and much stiffer than existing concrete structure.	$38 Million	24 Months	Requires massive new foundation anchors.	Moderate, Except High at Connection Locations.	Moderately High	Prevented at many locations.	Moderate
2) Exterior Shotcrete	"GOOD," If very strong and much stiffer than existing concrete structure.	$26 Million	30 Months	Requires strengthening of columns and footings due to weight.	Very high, with major drilling and doweling at window closures.	Very High	Prevented at many locations.	Significant
3) Exterior GFRP Composition	"POOR," As it requires concrete to crack up first.	$19 Million	30 Months	No change	Moderate	Moderate	Removed during construction and replaced for Full operability.	Slight
4) Exterior Steel Channel Box Frames	"EXCELLENT," If all elements remain elastic and undamaged (i.e. no ductility demand).	$7 Million	6 or 14 Months	No change	None	None (2 drill holes at each window, done at night)	Full operability except at end lites. These can swing open a half inch clear.	Moderate
5) Demolition and Reconstruction	a) EXCELLENT if built to 2003 IBC / NFPC Strength Codes; b) "GOOD" if built to 1997 UBC Code's Ductility.	$100 Million or more	36 Months	Rebuild	Very High	Very High	Full	None

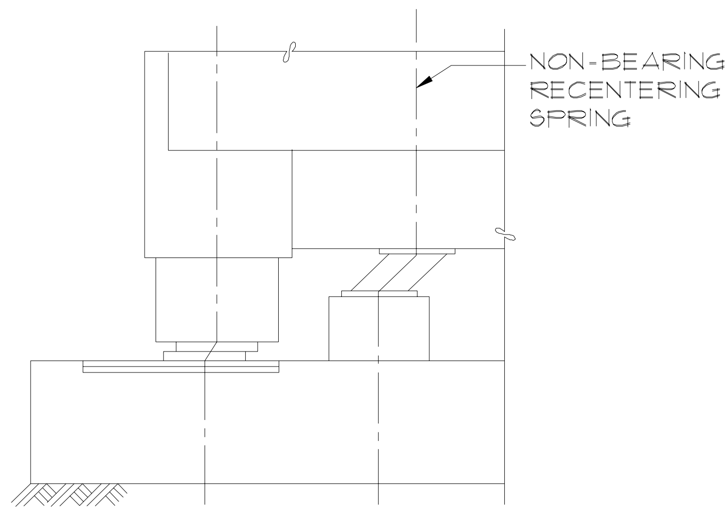
TERRORIST EXPLOSION BARRIERS: BUILDING ENERGY DISSIPATING SYSTEMS (BEDS)

Building Energy Dissipating Systems (BEDS) provide protection at the basement or lobby level during both strong blast overpressures and the strongest of earthquakes, such as the 1906 San Francisco ground motion. By decoupling an existing building from its foundation, a blast or earthquake can't deform the building's foundation beyond its calibrated sliding friction force, as chosen to inhibit structural damage.

BEDS can be installed very inexpensively at each building's lobby level or basement level, but the lobby is usually less costly when retrofitting existing buildings.



BEFORE AND AFTER

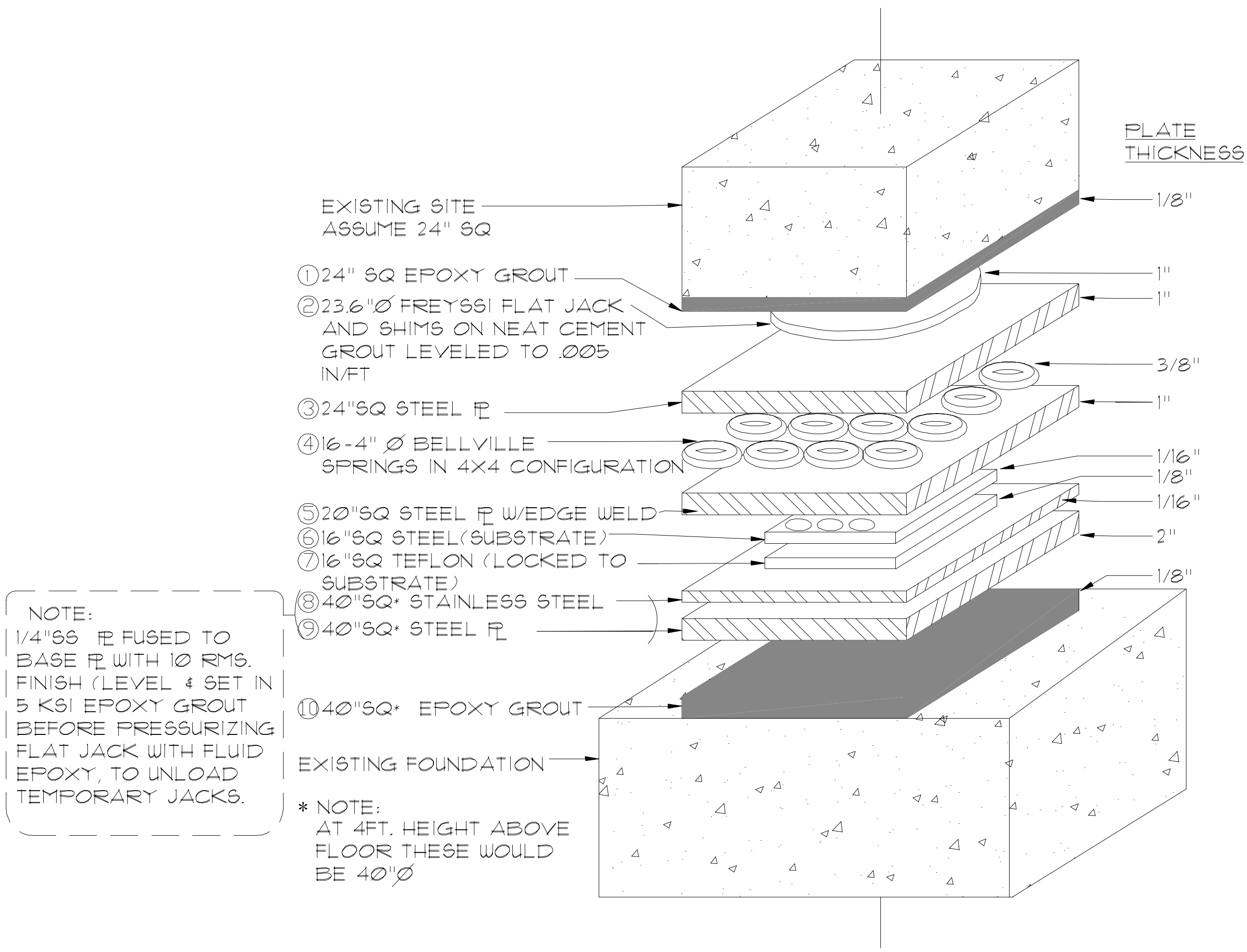


DURING A BLAST OR EARTHQUAKE

BEDS technology applied in the basement, usually uses small square Teflon lined plates, positioned above enlarged stainless steel plates to entirely cover the existing footings. By constructing the enlarged stainless steel bottom plates to fit over the entire footing, the column has lots of sliding room once the footing accelerates rapidly enough under the building and the calibrated coefficient-of-friction (as low as 0.04) is reached. The horizontal sliding force can't physically be exceeded. All columns and walls are thereby protected against both flexural damage at their top and bottom ends, as well as shear fracture at their mid-height.

BEDS technology applied at the first story, usually uses small circular Teflon lined plates, positioned above enlarged stainless steel circular plates that rest on the high strength reinforced concrete placed within the cylindrical steel jacking form. By constructing the enlarged stainless steel bottom plates to fit over the entire circular concrete area created inside the reusable steel jacking form, the column has lots of sliding room once the footing accelerates fast enough under the building and the calibrated coefficient-of-friction is reached.

The small rectangular Teflon lined plates simply slide about over the enlarged columns' stainless steel bearing plates, in a random whiplash fashion during an earthquake and in a linear direction following a blast impulse. When retrofitting existing columns, enlargement can be accomplished by temporarily jacking against a reusable circular steel form positioned in the "punching shear" zone, directly below and the 2nd floor girders. For steel columns, jacking lugs can be attached to column flanges by welding.



Before cutting a column to insert the prefabricated slide bearing, all calibrated bearings will have been exercised in the shop to assure their calibration. Once sliding begins, distortion of the elastomeric spring "in parallel" acts with the friction sliding force to cause the structure to decelerate after a blast or follow after the randomly moving foundation caused by the earthquake. The friction force is a vector always acting in the direction of *relative velocity* between the foundation and structure. The elastomeric spring always acts as a vector in the direction of *relative displacement* between the foundation and structure.

Additional steel springs can be added both in series and in parallel with the BEDS Teflon lined bearings. Elastomeric springs placed in parallel (See BEDS drawing) don't support any vertical weight but are attached at top and bottom with epoxy cement. They serve as re-centering springs, acting to resist off center alignment.

Steel spring bearing pads can be used beneath the small Teflon lined plates, in series, to uniquely modify the vertical spring stiffness of each slide-bearing connection. This enables the permanent "Freyssi flat jacks" to gradually transfer loads from the reusable temporary jacks.

Total control of a passive BEDS system stems from manufacturing control of 2-elements. These are the calibrated sliding friction shear force bearings and non-bearing re-centering shear springs, acting "in parallel". Both these shop fabricated and shop calibrated elements provide the structural engineer with quality control over the horizontal force transfer of earthquakes and blasts. Once the horizontal base shear reaches the reliably shop-calibrated coefficient-of-friction, ranging between a low of 0.04 and a high of 0.20, the foundation begins to slide a few inches beneath the columns and piers of the structure while dissipating vast amounts of energy as heat. Only then does the dormant in-parallel elastomeric spring begin exerting a re-centering force.

Installation of the system in new construction is obviously easy. Retrofit construction for existing columns and walls is far less costly than any other retrofit option available. Combined with the advantage of low cost is the very high earthquake and blast resistant performance standard attainable for very vulnerable existing buildings. Such buildings are quite brittle, having significant elastic strength but little inelastic ductility.

By limiting the horizontal base shear during the strongest of earthquakes or blast attacks to one-half the building's elastic strength, a safety factor of two can be established against structural damage to the building. This enhances life safety for people and assets to the highest possible performance standard during both earthquake and blast attacks.

When a nearby detonation causes a blast wave to resonate off the building, it impacts first on the bottom story and then "climbs" the building height. This causes the first story to slide into the building, creating eccentricity on the columns and walls until the upper stories are also accelerated as the blast pressure climbs up the building facade. Stability of the building can be designed into both the blast's acceleration deformation and the deceleration sliding configuration.

When a distant detonation causes a blast wave to reflect through the building, it hits the facade as a more uniform frontal pressure. This impulse is of much shorter duration than the natural period of the building hence resonance is not likely. Instead the building accelerates as a rigid body and need only be designed as a decelerating slide configuration. As this deformation configuration is a function of the calibrated friction coefficient and the building's natural frequency of vibration, design can determine the standoff perimeter needed to prevent collapse.